PULSE-RATE AND BLOOD-PRESSURE RESPONSES OF MEN TO PASSIVE POSTURAL CHANGES.*

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The development of the airplane has added interest to the circulatory response of men following passive alterations of body position, for the aviator is subjected frequently to sudden variations in body position, which are largely passive as far as his musculature is concerned. Changes in pulse-rate and blood-pressure correlated with changes in body position made by the subject, have been studied by many investigators, but the changes in circulation accompanying postural changes in which the subject is moved by some force outside of his body, have not received the same attention.

In experiments on animals Hill ('95) showed that the blood-pressure in the carotid artery was increased by tilting the animal from the horizontal to the head-down position and decreased by tilting from the horizontal to the head-up position. Barach and Marks ('13), working with young men fifteen to thirty years of age, on a tilting table, concluded that "when the element of muscular effort has been eliminated, change of body posture from the erect to the horizontal will cause an increase in the maximum pressure, a decrease in the minimum pressure and an increase in the pulse-pressure." Henderson and Haggard ('18) followed the circulatory responses in the head-down position of ten young men on the tilting board, and report that "in the inverted or head-down position (30 to 45 degrees) the heart-rate in ten men was slower than in the flat position by an average of 9.5 beats a minute and slower than the erect position by 17." Excepting two cases (in the tilt from the erect to the reclining position) all of the pulse responses were minus in the tilts which lowered the head and plus in those which raised the head. The responses in systolic and diastolic pressures were not so uniform. The systolic pressure of five of the ten men and the diastolic pressures of all ten fell on changing from the erect to the horizontal. On tilting from the horizontal to the head-down position the systolic pressure rose in some cases and fell in others, the subjects being about equally

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divided between the two responses. The same was true of the responses to the return tilt, *i. e.*, from the head-down position to the horizontal. The diastolic responses following both of these tilts were also about equally divided between plus and minus. Although the work of Stephens ('04) is not strictly comparable with the preceding articles because his subjects were not tilted except from the reclining to the head-down position, his averages of the responses in pulse-rate, and systolic-pressure to changes in body position are interesting in this connection. These averages show a decrease in the per minute heart-rate and an increase in the systolic blood-pressure from the erect position, through the sitting and reclining positions to the head-down position. Stephen's data were collected after the circulatory balance was reached by his subjects. More recently Barach ('19) summarizes the responses in pulse-rate, systolic and diastolic pressure of 48 normal adults to two passive tilts. When these subjects were tilted from the standing position to the reclining he found that the pulse-rate and diastolic pressure fell and the systolic pressure rose. Following the return tilt from reclining to standing position the pulse-rate and diastolic pressure rose and the systolic pressure fell.

These observations collectively suggest that the circulatory responses of men to passive tilts which lower the head are a decrease in the per minute pulse-rate, an increase in the systolic pressure (sometimes a decrease) and a decrease in the diastolic pressure (sometimes an increase).

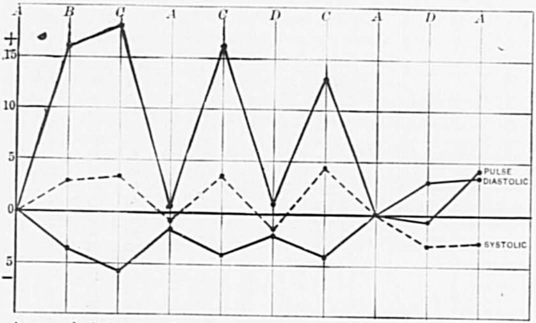
The present study was undertaken at the Medical Research Laboratory of the Air Service with a view to obtaining additional data on the constancy of these responses of men to passive postural changes of various sorts and on the degree of these responses.

Fifty young men, twenty to thirty-one years of age, drawn from the medical department and from the air service of the army, were used as subjects. Each man was given the routine physical examination by an internist and by an ear, nose and throat specialist before selection for these tilt tests. No man not reported sound was taken. All of the subjects were familiarized with the tilting table and its operation before the tests were made, to eliminate the factor of surprise. During the tests the subject refrained from talking and the observers spoke only when necessary.

The tilting tests were made by two observers, one taking the pulse counts and the other the blood-pressures throughout the test. The subject was placed on the tilting table and swung up into the horizontal plane, here termed the reclining position, after the blood-pressure apparatus was attached to the left arm (a Tycos apparatus was used and the readings taken by auscultation) the subject was undisturbed ten minutes, when the first records of pulse and blood-pressure were taken simultaneously. Three readings were made and the averages taken as the normals against which the subsequent readings in other positions were checked. As soon as the normals were established the subject was tilted quickly and quietly into the new position and a new reading taken. As assistants were always present to look after the mechanical side of the tilting the observers were able to make the first count of pulse-rate and the first measurements of blood-pressure within thirty seconds after the tilt. These figures have been recorded in the tables as the "immediate response." After the immediate response was recorded the subject was again undisturbed for five minutes. At the end of five minutes a second set of records were taken which have been termed the "response at the end of the fifth minute." These readings completed, the subject was tilted to the next position and the process repeated. Effort was made to take all readings at the end of expiration, but this was not always possible. From these several sets of readings the amount and direction of change in the pulse-rate and blood-pressures during the first thirty seconds after the body position was altered the amount and direction of change at the end of the fifth minute and the amount and direction of change during the five minutes in each position were obtained. In establishing these values the readings in a given position were compared with those taken at the end of the fifth minute in the preceding position. Five minute intervals were chosen because it was found by preliminary tests in which minute to minute readings were taken, that the subjects generally reached their maximum responses and adjustments to the new position within the first three minutes after the tilt was made.

Two series of tilts were used. In the first series the subject was tilted from the reclining position to head up 45 degrees, head up 45 degrees to standing, standing to reclining, reclining to standing, standing to head down 45 degrees, head down 45 degrees to standing. In the second series the first three changes of position were identical with the first three of the first series, *i. e.*, from reclining through head up 45 degrees and standing to reclining again. Then followed tilts from reclining to head down 45 degrees and head down 45 degrees to reclining (see Chart).

General Responses. Considering the responses in pulse-rate, systolic pressure and diastolic pressure separately, correlated only with the changes in the position of the subjects, the responses in pulse-rate were the most uniform of the three. Ninety per cent. of all cases in which the head was elevated during the tilt showed an immediate rise in pulse-rate and 84 per cent. had a higher pulse-rate at the end of the fifth minute after a tilt which elevated the head than at the end of the fifth minute in the previous position. The opposite tilts, those in which the head was lowered, gave much the same grouping of cases, with the opposite pulse response. Ninety-one per cent. showed an immediate fall in pulse-rate on lowering the head and 86 per cent. had a lower pulse-rate at the end of the fifth minute than in the previous position. The predominant pulse responses, therefore, to all changes of position taken collectively were (1) an increase in pulse-rate—plus response—on raising the head, and (2) a decrease in pulse-rate—minus response—on lowering the head. All of the several types of tilts produced these responses, as from 62 to 100 per cent. of the cases in each tilt gave the responses designated above as the predominant responses. In the main these predominant responses were supported by larger percentages immediately after the tilt was made than at the end of the fifth minute, suggesting that the pulse response was compensatory to the sudden change in position of a considerable volume of blood by gravity, and that additional responses during the next five minutes completed the adjustments to the new body position. This is confirmed by the changes in blood-pressure during the five-minute interval. In some of the tilts these readjustments amounted to a change in the character of the blood-pressure response from minus to plus. Although in other tilts this shifting of blood-pressure was not so profound, in all tilts excepting that from head down to standing more of the subjects showed a zero blood-pressure response at the end of the fifth minute than immediately after the change of position (Table I).



Average deviations in pulse-rate, systolic pressure and diastolic pressure from the reclining normals at the end of the fifth minute after each tilt. Tilts plotted in sequence used in the tests. Pulse-rate plotted in beats per minute and blood-pressures in millimeters of mercury: *A*, reclining; *B*, head up 45 degrees; *C*, standing; *D*, head down 45 degrees.

The blood-pressure responses were not so sharply grouped as were the pulse-rate changes. The predominant responses in general, as indicated by the highest percentages, were a fall in systolic pressure and a rise in diastolic pressure following those tilts which raised the head; and a rise in the systolic pressure and a fall in the diastolic pressure following those tilts which lowered the head. The diastolic pressure varied in the same direction as the pulse-rate and the systolic pressure in the opposite direction. The predominant blood-pressure responses were supported by much smaller percentages than were the changes in pulse-rate. In several of the tilts the cases were about equally divided between plus and minus blood-pressure responses, indicating that the blood-pressure responses were much less constant than the pulse-rate changes.

TABLE I.—RESPONSES TO TILTS.

Tilt.	Cases.	Pulse.			Systolic.			Diastolic.		
		Rose.	Held.	Fell.	Rose.	Held.	Fell.	Rose.	Held.	Fell.
All tilts raising head .	244	**90**	5	5	17	9	**74**	**58**	7	35
		84	5	11	21	21	**58**	**60**	20	20
All tilts lowering head	108	8	1	**91**	**48**	9	43	18	8	**74**
		6	8	**86**	**48**	13	39	24	9	**67**
Head down to reclining	46	**79**	4	17	38	22	38	34	22	**44**
		69	14	17	38	18	**44**	**47**	23	30
Head down to standing	32	**100**	0	0	33	0	**67**	**67**	0	33
		100	0	0	17	17	**67**	**83**	0	17
Reclining to head up 45 degrees . . .	58	**100**	0	0	4	4	**92**	**82**	4	14
		100	0	0	18	14	**68**	**76**	10	14
Reclining to standing	50	**100**	0	0	12	8	**80**	**68**	4	28
		100	0	0	20	24	**66**	**68**	24	8
Head up 45 degrees to standing . . .	58	**79**	17	4	14	7	**79**	41	4	**55**
		62	7	31	18	27	**55**	**41**	24	35
Reclining to head down 45 degrees . . .	34	17	0	**83**	12	12	**76**	36	12	**52**
		12	17	**71**	24	12	**64**	**59**	17	24
Standing to reclining	42	5	0	**95**	**76**	0	24	14	5	**81**
		5	5	**90**	**71**	5	29	19	5	**76**
Standing to head down 45 degrees . . .	32	0	6	**94**	**50**	19	31	19	0	**81**
		0	0	**100**	**50**	25	25	19	6	**75**

Data given in percentages for direct comparison. First line in each pair gives the immediate response as compared with the normal in the previous position; the second line gives the response at the end of the fifth minute after the tilt.

Three separate tilts did not follow the predominant responses of blood-pressure as determined by the mass data of all classes. In the reclining to head-down tilt the systolic responses of 76 per cent. of the cases were minus immediately after the tilt, and 64 per cent. held a systolic pressure lower than the reclining normal to the end of the fifth minute. The diastolic pressures of 52 per cent. also fell below the reclining value immediately after the tilt (the response expected from the predominant responses of the mass data of head lowered tilts), but in 59 per cent. of the cases of this tilt the diastolic pressure rose during the five-minute interval above the reclining normal. In the reclining to head-down tilt, therefore, the pulse response followed the typical response of all head-down tilts, the systolic pressure fell instead of rising and the diastolic pressure fell as expected immediately after the tilt but rose above the reclining value during the next five minutes. The other two exceptions to the predominant responses of the mass data were in the diastolic pressure responses. In both the head down to reclining and head up 45 degrees to standing tilts the immediate diastolic response was a fall in pressure below the former value, followed by a rise during the next five minutes. The diastolic exceptions in all three tilts, therefore, were all of one type, an initial fall regardless of the position from which the tilt was made, followed by a rise above the value in the preceding position during the next five minutes. It is to be noted also in this connection that in each of the three tilts in which the diastolic pressure did not follow the predominant response of the mass data the cases of each tilt were about evenly divided between plus and minus response. As is shown under the discussion of the degree of change in these three tilts the actual amount of change in pressure measured in millimeters of mercury was slight and the diastolic pressures in these three tilts may represent indifferent responses.

If the predominant responses in pulse-rate, systolic pressure and diastolic pressure, as determined in Table I by the largest percentage of cases in each tilt group, be summarized in a formula (P = pulse, S = systolic pressure, D = diastolic pressure), $P + S - D +$ represents the predominant responses of the largest percentage of cases to a passive tilt in which the head was raised, regardless of the initial position from which the tilt was made. Similarly, $P - S + D -$ represents the predominant responses of cases in which the head was lowered, excepting the tilt from reclining to head down. In this tilt the largest percentage of cases gave the $P - S - D +$ responses.

These three formulæ of responses from the mass data were applied to the actual records of each individual case to determine the degree of correlation existing between the three responses of pulse-rate and systolic and diastolic pressures. The responses at the end of the fifth minute after the tilt were used (Table II). Only one-third of all cases in which the head was elevated during the tilt gave the expected responses in all three variables, pulse-rate, systolic and diastolic pressures. In the tilts lowering the head the percentage was slightly higher but still below 50 per cent. In only two tilts did the percentages of cases agreeing with the formula of responses exceed 50 per cent. in the head down to standing tilt and in the reclining to head up 45 degrees tilt. Cases giving any two of the predicted responses were more numerous, including 50 per cent. or more of the subjects in each tilt with the exception of the head down to reclining tilt. A comparison of the cases giving any two of the expected responses suggests there is little difference in the constancy of the systolic and diastolic blood-pressures, as the *P S* and *P D* groups were about the same. Fewer subjects gave both of the predicted blood-pressure responses than gave the predicted pulse and either one of the blood-pressure responses. This was excepted from the summary of the mass data (Table I) as the pulse-rate changes were the most constant of the three responses. This confirmation of the grouping in Table I gives added value to those percentages, which show not only the relative constancy of each response but also that the predominant method of compensation was a change in pulse-rate.

It is evident from Table II that the responses to changes in position were not equal in the three variables, pulse-rate, systolic pressure and diastolic pressure, and that there was no stereotyped response which included the majority of cases. Satisfactory compensations, at least such as would maintain the individual for five minutes without loss of consciousness (none of the subjects fainted during the tilts) were made by other combinations of pulse, systolic and diastolic responses than those expected from the mass data.

TABLE II.—CORRELATIONS OF THE THREE RESPONSES, PULSE-RATE (P), SYSTOLIC PRESSURE (S) AND DIASTOLIC PRESSURE (D). DATA IN PER CENT. OF CASES GIVING RESPONSES INDICATED.

Tilt.	P + S − D + Per cent.	P − S − Per cent.	P + D + Per cent.	S − D + Per cent.
Head down to reclining	13	30	39	26
Head down to standing	67	67	83	67
Reclining to head up 45 degrees	55	72	70	55
Reclining to standing	32	50	56	32
Head up 45 degrees to standing	21	48	27	30
All head up cases	33	52	50	38
	P − S + D − Per cent.	P − S + Per cent.	P − D − Per cent.	S + D − Per cent.
Standing to head down	31	50	70	31
Standing to reclining	38	57	62	43
	P − S − D + Per cent.	P − S − Per cent.	P − D + Per cent.	S − D + Per cent.
Reclining to head down	47	58	53	47

Degree of Response. In Fig. 1 the mean values of change in pulse-rate per minute and blood-pressure in millimeters of mercury have been plotted, taking the several tilts in the sequence in which they were made on the subject. The mean values were obtained after the actual values of all individual cases had been plotted by classes. As the pulse-rate counts were made in twenty-second units and multiplied by three a deviation of plus or minus one count by the observer has been allowed, and similarly a deviation of plus or minus one unit (2 mm.) on the Tycos dial has been allowed in the blood-pressure readings. The zero class of the pulse values included, therefore, all cases whose responses varied from plus three beats to minus three beats per minute and the zero classes in the blood-pressure all from minus 2 mm. to plus 2 mm. The class ranges for pulse-rates were nine beats per minute and for blood-pressure 6 mm. of mercury.

The tilts from reclining to head up 45 degrees and from reclining to standing gave almost identical degree changes, being *P* +16 beats, *S* −3.5 mm., *D* +3 mm. and *P* +16, *S* − 4, *D* +3.5 respectively at the end of the fifth minute after the tilt. When the standing position was reached by two tilts, *i. e.*, reclining to head up 45 degrees and head up 45 degrees to standing, greater deviations from the reclining normals of pulse-rate, systolic and diastolic pressures were obtained, the responses at the end of the fifth minute of standing after these two tilts being, *P* +18, *S* −5.5, *D* +3.5. These values equal or exceed each of the three responses to either the reclining to head up 45 degrees tilt or the reclining to standing tilt. When the standing position was reached by one tilt from the head-down position, *i. e.*, the head down to standing tilt the pulse response was smaller and the diastolic response greater than either of the other two standing values. The response at the end of the fifth minute of standing after the head down to standing tilt were *P* +12, *S* −2, *D* +6 and the deviations from the reclining normals *P* +13, *S* −4, *D* +4.5.

In the reverse tilts, standing to reclining, opposite responses obtained, *P* −17.5, *S* +4, *D* −4, so that the readings at the end of the fifth minute in the reclining position were almost identical with the normals taken in the reclining position. In the standing to head-down tilt the response in pulse was not as great as in the standing to reclining tilt being *P* −15, *S* +2, *D* −5. Although less than the responses from standing to reclining these values following the standing to head-down tilt are fairly close reverse responses to those following the head down to standing tilt. The responses after that tilt were *P* +12, *S* −4, *D* +4.5. It is evident that a subject does not relax as completely in the unusual position of head down 45 degrees as in the reclining position, and the factor of muscular effort, either conscious or unconscious, is not completely eliminated in the head-down position. Similarly a certain amount of muscular effort on the part of the subject cannot be avoided in the standing position even though the subject is brought to this position by forces outside of his body. In the head down to standing tilt, therefore, the muscular effort of the subject and the movement of the blood by gravity both contributed to the reactions of the subject.

In order to ascertain the responses to the head-down position following a tilt from a position in which the muscular effort of the subject was eliminated as far as possible, part of the subjects were tilted from the reclining to the head-down position and then back to the reclining position. The responses at the end of the fifth minute in the head-down position following the reclining to head-down tilt were quite different from those at the end of the fifth minute in the head-down position following the standing to head-down tilt. Following the reclining to head-down tilt the deviations from the reclining normals were P −0.5, S −4, D +3 at the end of the fifth minute as compared with P +1, S −2.5, D−1.5 at the end of the fifth minute after the standing to head-down tilt. After the return tilt, head-down to reclining, the subjects did not return to the reclining normals in five minutes, the average deviations from the reclining normals being P +4, S −2.5, D +3.5.

From these various degree values it seems that the subjects examined made rather complete adjustments in five minutes to tilts in the reclining-standing quadrant, as the changes in pulse and blood-pressure in one direction are offset by approximately equal changes in the opposite direction on reversing the tilt. In the reclining to head-down quadrant the responses were much less uniform, and the circulatory balance was probably not established in the five-minute interval. Tilts starting in the reclining-standing quadrant and ending in the reclining-head-down quadrant, or *vice versa*, gave more uniform and also more profound responses than tilts in the reclining-head-down quadrant alone. These tilts, however, which carried the subject through more than 90 degrees, showed the disturbing effect of the head-down position, either at the beginning or the end of the tilt, upon the general compensations of the body to changes in position.

Considering the mass data of all cases collectively the responses obtained from these fifty men were in general the responses expected from the review of previous experimentation. The formulæ $P+$ $S-$ $D+$ for the tilts raising the head and $P-$ $S+$ $D-$ for those lowering the head, included the largest percentages of responses in all tilts excepting the reclining to head-down tilt, the mass responses of which were $P-$ $S-$ $D+$. The application of these formulæ, however, to the individual cases showed that a relatively low percentage of the individuals actually gave these three responses simultaneously and that these formulæ were therefore unreliable for the study of individual subjects even among men who had been pronounced in good physical condition. The response to passive changes in body position, as evidenced by the data here offered, was primarily one of change in pulse-rate. The blood-pressure responses were much more subject to individual variation in the general adjustment following these passive body position changes, although the blood-pressure responses did show definite groupings in the mass data. As the effect of the shifting suddenly of a quantity of blood by gravity could produce through its effect on the nervous mechanism controlling the heart, changes in pulse-rate such as followed the changes in body position, and as several other factors are involved in the blood-pressure changes, a greater constancy of the pulse responses might be expected.

The responses in systolic pressure to the reclining to standing tilt were so different from those given by Crampton ('13), for healthy men on standing from the reclining position that the mass data may be reviewed here for comparison. Crampton states "that in the perfectly normal there occurs upon rising from the recumbent position a vasoconstriction effort which squeezes these veins (splanchnic) and raises the blood-pressure, which more than overcomes the hydrostatic load." In the tilt from reclining to standing the mass response was a fall in systolic pressure, supported by 80 per cent. of the cases immediately after the tilt, and by 66 per cent. at the end of the fifth minute, instead of the rise in systolic pressure found by Crampton in the men who stood voluntarily. As the subjects used in these tilting tests had been reported sound by the examining surgeons the vasomotor tone of the subjects was presumably good. The fall in systolic pressure following the tilting of these men from reclining to standing suggests either a lag in this compensatory vasoconstriction effort or a greater demand for compensation than could be met by the splanchnic area alone. As the percentage of cases giving the fall in systolic pressure fell during the five-minute interval from 80 to 66 per cent. there was some compensation which raised the blood-pressure during the five-minute period in at least 14 per cent. of the cases. In the case of the individuals rising by their own muscular efforts the tightening of various muscles of the body which would occur in the act of rising, would in part prevent the fall in pressure which took place in the reclining subjects who were suddenly tilted into the standing position. The relative demand, therefore, for compensation from the splanchnic vessels would be greater in the case of the tilted subjects than in that of the subjects rising by their own muscular effort.

Summary. 1. In general tilts elevating the head gave a rise in pulse-rate, a fall in systolic pressure and a rise in diastolic pressure, and those lowering the head a fall in pulse-rate, a rise in systolic pressure and a fall in diastolic pressure. The conspicuous exception to these responses was the reclining to head-down tilt in which the largest percentage of cases gave a fall in pulse-rate, a fall in systolic pressure and a rise in diastolic pressure.

2. The individual data showed that only a little over one-third of all cases gave the three responses in pulse-rate, systolic and diastolic pressures expected from the mass data, simultaneously.

3. Tilts from reclining to head down 45 degrees and return gave the least constant responses of all the tilts used.

4. The tilt from reclining to head up 45 degrees produced almost the same degree of responses as the tilt from reclining to standing.

5. With the exception of the tilts in the head down to reclining quadrant the responses given to any tilt were offset by approximately equal opposite responses when the tilt was reversed.

6. The initial and final positions of the subject had more effect on the degree of responses following a tilt than did the distance travelled by the subject during the tilt.

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LABORATORY AIDS IN THE DIAGNOSIS OF GONOCOCCAL INFECTIONS, WITH SPECIAL REFERENCE TO THE GONOCOCCUS COMPLEMENT-FIXATION TEST.

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The present intensive campaign for the education of the general public in regard to the incidence, treatment and prevention of venereal diseases will, it is hoped, do much to lead to their early recognition, and, following upon this, and instructions as to their infectivity—which must, of necessity, form part of their treatment—great strides in their prevention are to be hoped for.

Indeed, it is now not an infrequent occurrence for those about to marry to seek information as to their freedom from venereal infection and because of this fact, and because, particularly in cases of long standing or those whose infection long antedates their visit to the doctor, the question as to their ability to infect others is a matter difficult to decide, a *resume* of the laboratory aids in the diagnosis of gonococcal infections seems timely.

In spite of the fact that the recognition of the typical case of gonorrhea is, as a rule, a matter of no difficulty, there are a number of cases of urethritis, especially in the female, where the diagnosis is not readily to be made.

A wrong positive diagnosis is an injury to the patient not readily